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Francine E. Smith

Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney Docket No. 990646/LH

Pursuant to 37 CFR 1.53(b), transmitted herewith for filing is the patent application of

Inventor(s):

Thord Agne Gustaf NILSON

Title:

"METHOD FOR RESTARTING A SYNCHRONOUS PERMANENT MAGNET MOTOR STILL ROTATING"

Priority Claim (35 U.S.C. 119) is made, based upon:

Swedish Patent Application Number 9803532-2 filed October 16, 1998

Enclosed herewith are:

[X] Specification (Description, Claims, Abstract): Pages 1 - 7; Number of claims 1 - 7

[X] Declaration and Power of Attorney (executed)

[X] 2 Sheets of drawings, Figures 1 - 3 [X] Formal [ ] Informal

[X] Assignment and Form PTO-1595 Recordation Form Cover Sheet and Check for $40.00

[ ] Certified copy (ies) of priority document(s) identified above

[ ] Information Disclosure Statement including Form PTO-1449

[X] Preliminary Amendment - **TO REMOVE MULTIPLE DEPENDENT CLAIMS**

[ ] Verified Statement(s) Claiming Small Entity Status

[X] Receipt Postcard

	Number Filed		Number Extra	Rate	Calculations
Total Claims	9 -20	=	0	x $18.00 =	$ -
Independent Claims	1 - 3	=	0	x $78.00 =	$ -
MULTIPLE DEPENDENT CLAIMS				+ $260.00 =	$ -
				BASIC FEE	$ 760.00
				Total of above Calculations	$ 760.00

To the extent not tendered by check, authorization is given to charge any fees under 37 CFR 1.16 and 1.17 during pendency of the application, or to credit any overpayment, to Deposit Account No. 06-1378. Duplicate copy of this letter is enclosed.

FRISHAUF, HOLTZ, GOODMAN, LANGER & CHICK, P.C.

By: _____
HERBERT GOODMAN - Reg. No. 17,081

HG/fs
Encs.

Attorney Docket No. 990646/LH

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant(s): Thord A. G. NILSON

Serial No. :

Filed : Concomitantly Herewith

For : METHOD FOR RESTARTING A SYNCHRONOUS PERMANENT MAGNET MOTOR STILL ROTATING

Art Unit :

Examiner :

"Express Mail Mailing Label No.: EL 270 015 784 US
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Francine E. Smith

Francine E. Smith

In the event that this Paper is late filed, and the necessary petition for extension of time is not filed concurrently herewith, please consider this as a Petition for the requisite extension of time, and to the extent not tendered by check attached hereto, authorization to charge the extension fee or any other fee required in connection with this paper, to Account No. 06-1378.

PRELIMINARY AMENDMENT FILED CONCOMITANT WITH APPLICATION

Assistant Commissioner for Patents

S I R :

Please amend the application as follows.

IN THE CLAIMS:

Claim 3, line 1, delete "or 2".

Claim 4, line 1, delete "or 2";

line 4, after "give" delete "an" and insert --a--.

Please add the following claims 8 and 9.

--8. Method according to claim 2, wherein the motor with said output stage of said drive unit is momentarily short-circuited at two or more occasions at certain time intervals, and

the current magnitude values measured at each short-circuiting occasion is compared to those measured at another short-circuiting occasion or occasions to determine the difference in phase angle obtained during said certain time interval or intervals and, hence, the actual rotor speed.

9. Method according to claim 2, wherein the duration of said short-circuiting moment is chosen so as to obtain a magnitude of the current generated by the motor having an amplitude high enough to give a favourable current measurement accuracy.--.

REMARKS

The present amendment removes the multiple dependent claims without changing the scope of coverage.

Respectfully submitted,

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Method for restarting a synchronous permanent magnet motor still rotating.

The invention relates to a method for restarting a synchronous permanent magnet motor still rotating and connected to a drive unit with a variable output AC voltage.

In particularly, the invention concerns a method for resuming operation of a 3-phase synchronous permanent magnetic motor by phasing-in the variable output drive unit relative to the actual speed and rotational angle of the motor rotor, wherein the drive unit has a DC-link with a voltage measuring means and current measuring means on at least two of the output phases.

In prior art technique, phasing-in of a drive unit in relation to the actual speed and position of a rotating motor has been performed by using a voltage sensing and measuring device connected to the three output stage outputs. This device complicates the drive unit unnecessarily, and since it is desirable to make the drive unit simpler, more reliable and less expensive it is an object of the invention to provide a drive unit having the same functional features without including this voltage sensing and measuring device.

A preferred application example of the invention is described below in further detail with reference to the accompanying drawings.

On the drawings
Fig. 1 shows a drive unit and motor circuitry according to the invention.
Fig. 2 shows a diagram illustrating current / time relationship during short-circuiting of the motor.

Fig. 3 shows a stator-referenced d / q diagram, illustrating the momentary current and angular position of the rotor at short-circuiting of the motor.

The drive unit shown in Fig. 1 is connected to a motor M and comprises a DC-stage which is powered by a battery or, dependent on the actual field of use, by an AC net source via a rectifier.. A DC-BUS feeds a direct current to an output stage which comprises three phases U, V and W and six power switches T1 - T6 with free-wheeling diodes. A voltage measuring means is connected to the DC-BUS to detect the DC voltage.

A current measuring means (not shown per se) is connected to two of the output phases U and V so as to detect the instantaneous values of the motor phase currents I_U and I_V. The states of the power switches T1 - T6 are controlled in a conventional way by a PWM controller (not shown).

The operational features of the illustrated drive unit as well as the phasing-in procedure of the latter at restarting the motor is described below with reference to the accompanying drawing figures. At the start of this procedure, it is assumed that in an initial condition all six power switches T1 - T6 are in their off conditions, and the motor M is rotating at an unknown speed.

The phasing-in procedure comprises the steps of short-circuiting momentarily the output stage of the drive unit, thereby measuring the current variations in two of the motor phases. In Fig.2, there is illustrated how the currents I_U and I_V in two motor phases vary over time during two momentary short-circuiting occasions performed within a certain time interval. The same current variations are illustrated in Fig.3 in a d/q planet diagram. The measured current values in relation to the duration of the

short-circuiting step and in relation to each other provides information of the actual speed and rotor position.

Referring to the diagramatic illustrations, a first short-circuiting starts in point t_1 , wherein the power devices T2, T4 and T6 are turned on and the currents I_U and I_V start rising. At t_2 the values of the currents I_U and I_V are sampled, and at t_3 the power devices T2, T4 and T6 are turned off. At point t_{3A} the currents are decreasing back to zero.

From the currents sampled in t_2 , which are correlated to the angular rotor position in point t_2 , the angle alfa-t_2 may be calculated. See Fig. 3. The radius R of the circle going through the current curves at t_2 is proportional to the motor speed divided by the circuit inductance, which is the motor inductance and eventual externally connected filter, provided the time intervals are chosen so as to make the circuit resistance neglectable. Thus, knowing the inductance in the motor circuit and the motor voltage constant it is possible to calculate the approximate motor speed.

It should be noted though, that in Fig. 3, the phase displacement during short-circuiting is illustrated in a somewhat exaggerated way in order to show more clearly the course of events.

In order to improve the speed calculation accuracy and to make a speed estimation without knowing the motor inductance, another short-circuiting steps may be performed at a later occasion. Accordingly, at t_4 the power devices T2, T4 and T6 are turned on, and the currents I_U and I_V start rising. At t_{4A} , the current values have increased to a certain extent, and at t_5 the current values are sampled.

At t_6 , the power devices T2, T4 and T6 are turned off, and the current values start decreasing via point t_{6A} back to zero. From the current samples taken at t_5 , it is possible to calculate the angle alfa-t_5, which is correlated to the angular position of the rotor at t_5.

Now, by dividing the angular interval: alfa-t_5 – alfa-t_2 by the time interval: $t_5 - t_2$ there is obtained the electrical speed of the motor M, which also gives the frequency to be used at phasing-in the drive unit.

These events may be repeated with successively larger intervals until there is obtained an accurate enough motor speed estimation.

In order to adjust the current response amplitude, the short-circuiting duration may simply be extended, i.e. the value of $t_2 - t_1$ and the value of $t_5 - t_4$. See Fig. 2.

For restarting the motor, the correct phase, frequency, and amplitude of the generated voltage has to be set to match the motor voltage. The generated phase and frequency are known by measurement, and the motor voltage is either calculated from: motor-frequency * motor-voltage-constant, or derived from the radius R of the current circle. See Fig. 3.

The correct drive unit voltage output is either measured or estimated on the DC-BUS voltage.

When the PWM controller has been set to generate the matching voltage, frequency and phase of the motor, the actual switching of the power transistors can be established. The motor is now restarted, and the PWM controller and switches will from now on operate in the conventional way.

Claims.

1. Method for restarting a three-phase synchronous permanent magnet electric motor having its rotor still at rotation, wherein the motor is connected to a drive unit having a DC-stage with a voltage measuring means, a variable voltage and frequency output stage having power switching devices, and a means for determining the current in at least two of the output phases from said drive unit, *c h a r a c t e r i z e d* by the following measures:

I) short-circuiting momentarily the motor with said output stage,

II) detecting during said short-circuiting moment the current magnitudes generated by the motor in at least two of the motor phases,

III) calculating during said short-circuiting moment the phase angle generated by the motor,

IV) determining the rotor speed and position,

V) synchronizing the drive unit with the rotor, and

VI) restarting the motor.

2. Method according to claim 1, wherein the voltage amplitude generated by the motor is calculated.

3. Method according to claim 1 or 2, wherein the motor with said output stage of said drive unit is momentarily short-circuited at two or more occasions at certain time intervals, and the current magnitude values measured at each short-circuiting occasion is compared to those measured at another short-circuiting occasion or occasions to determine the difference in phase angle obtained during said certain time interval or intervals and, hence, the actual rotor speed.

4. Method according to claim 1 or 2, wherein the duration of said short-circuiting moment is chosen so as to obtain a

magnitude of the current generated by the motor having an amplitude high enough to give an favourable current measurement accuracy.

5. Method according to claim 1, wherein said means for determining the current in at least two of the output phases of said drive unit is connected directly to the motor phases.

6. Method according to claim 1, wherein said means for determining the current in at least two of the output phases of said drive unit is connected to said power switching devices.

7. Method according to claim 1, wherein said means for determining the current in at least two of the output phases of said drive unit is connected to said DC-stage.

Abstract.

A method for restarting a three-phase synchronous permanent magnet motor in which the rotor is still rotating and in which the motor is connected to a drive unit having a DC-stage with voltage measuring means, a variable voltage and frequency output stage including power switching devices, and a means for determining the current in two of the output phases from the drive unit, wherein the motor with the output stage is momentarily short-circuited, the current magnitudes generated by the motor in the two output phases are measured during the short-circuiting moment, the phase angle generated by the motor during the short-circuiting moment is calculated, the rotor speed is determined, and the drive unit is synchronized with the rotor to enable restarting of the motor.

FIG 1

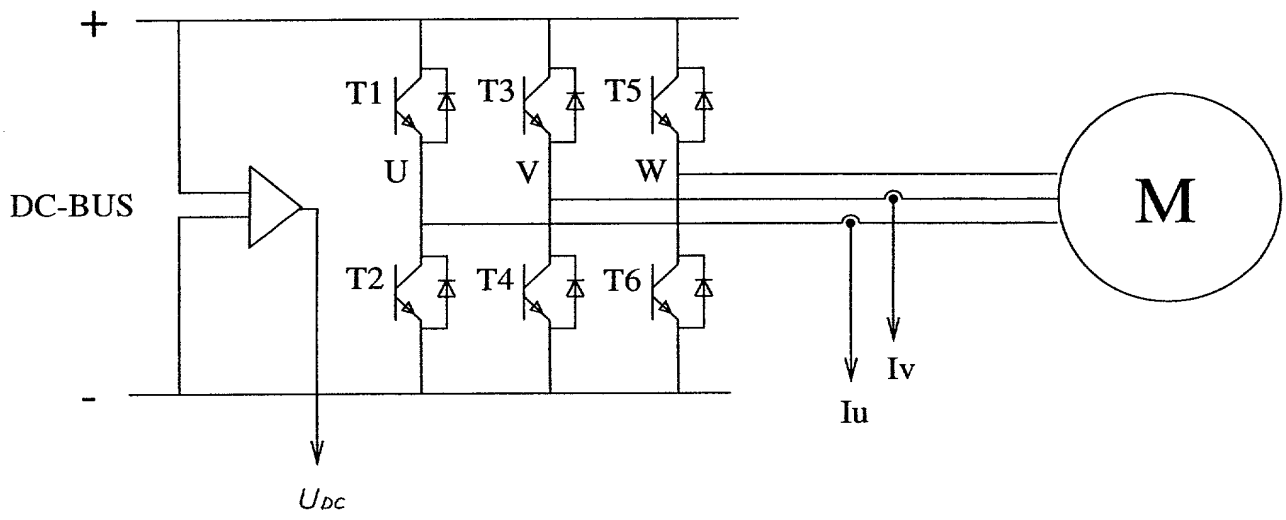


FIG 2

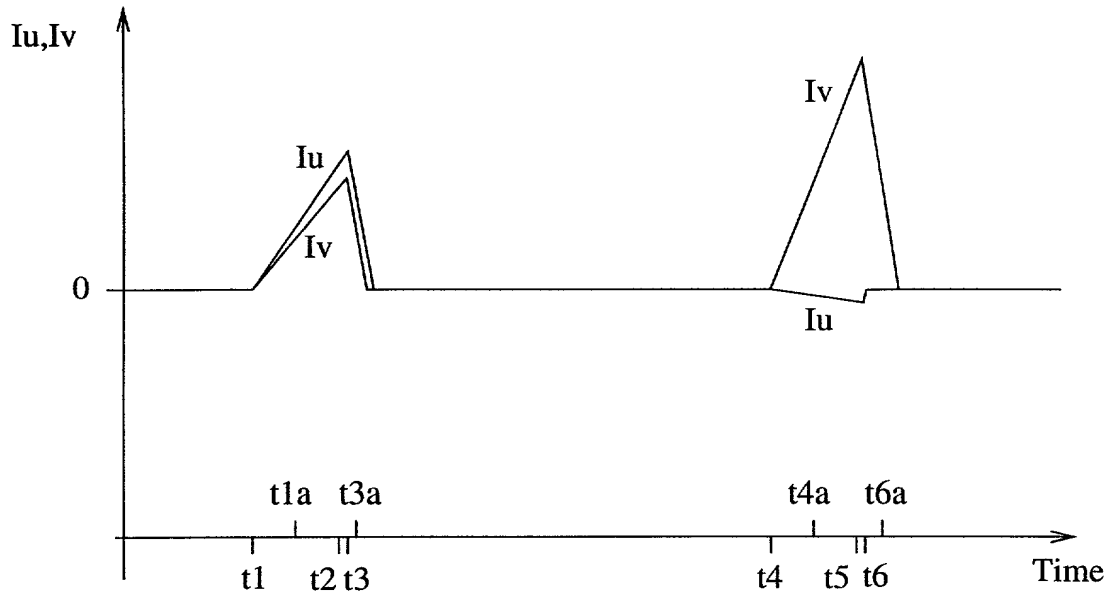
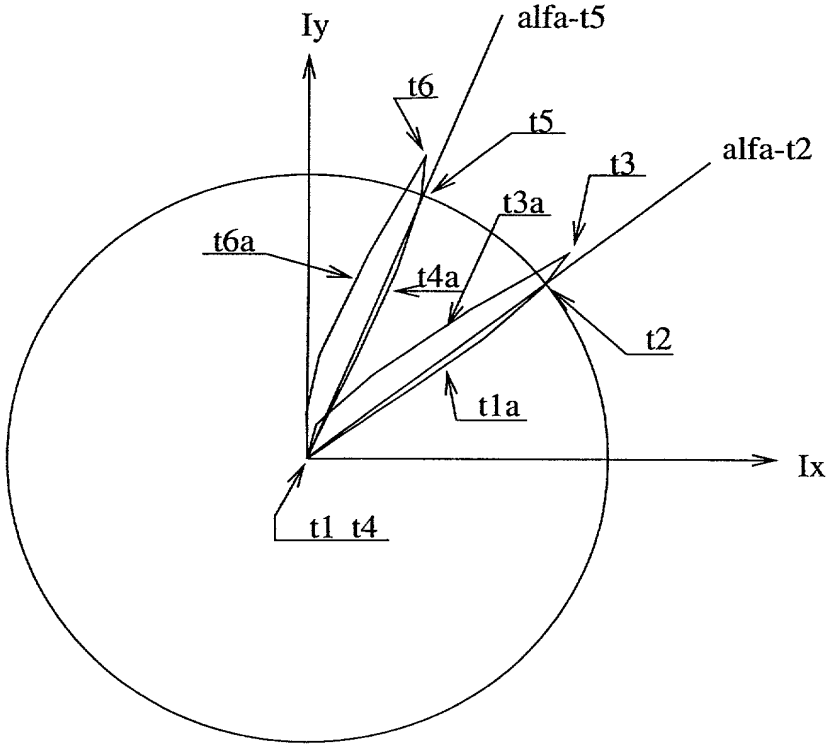

Iu,Iv
Iu
Iv
0
Iv
Iu
t1a t3a
t4a t6a
t1 t2 t3
t4 t5 t6
Time

FIG 3


Iy
alfa-t5
t6
t5
alfa-t2
t3
t3a
t6a
t4a
t2
t1a
Ix
t1 t4

10/96FHGL&C U.S. Attorney Docket _____

APPLICATION FOR UNITED STATES LETTERS PATENT

Declaration and Power of Attorney

As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD FOR RESTARTING A SYNCHRONOUS PERMANENT MAGNET MOTOR STILL ROTATING.

the specification of which is attached hereto.

I have reviewed and understand the contents of said specification, including the claims.
I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR §1.56.

I claim priority benefits under 35 USC §119 of: (i) any foreign application(s) for patent or inventor's certificate listed below; or (ii) any United States provisional application(s) listed below; and have also identified below any foreign application(s) for patent or inventor's certificate, or PCT international application having a filing date before that of the application(s) on which priority is claimed.

COUNTRY	APPLICATION NUMBER	DATE (day, month, year)	PRIORITY CLAIMED
Sweden	9803532-2	16 OCT 1998	yes X no _____
			yes _____ no _____

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I appoint the following attorneys to prosecute this application and to transact all business in the U.S. Patent & Trademark Office connected therewith: Stephen H. Frishauf, Reg. No. 16,233; Leonard Holtz, Reg. No. 22,974; Herbert Goodman, Reg. No. 17,081; Thomas Langer, Reg. No. 27,264; Marshall J. Chick, Reg. No. 26,853; Walter J. Baum, Reg. No. 20,641; Richard S. Barth, Reg. No. 28,180; Douglas Holtz, Reg. No. 33,902; and Robert P. Michal, Reg. No. 35,614.

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Type: Thord Agne Gustaf NILSON	Citizen of: Sweden	
Sign:	Date:	Residence (City and Country): Post Office Address:
Type:	Citizen of:	
Sign:	Date:	Residence (City and Country): Post Office Address:
Type:	Citizen of:	